THE HEATING OF THE INTERSTELLAR MEDIUM BY MIRA STARS

L. CARRASCO AND G. GRASDALEN
Berkeley Astronomy Department, University of California

As a long-period variable star crosses the gaseous component of the galactic plane, the expanding envelope, the product of the mass loss process occuring in this type of star, is stopped, transferring its translational kinetic energy to the interstellar medium. This process involves a significant amount of energy since the Mira variables have large velocity dispersions as well as large systematic departures from circular motion.

In order to estimate the amount of energy transferred by this process we have redetermined the density of Mira-type stars in the solar neighborhood. Counts of Mira variables contained in the California Institute of Technology infrared catalog, gave a density of Mira stars with periods longer than 375 days of $N_0 = 0.18 \times 10^{-6}$ pc^{-3}. This number density was scaled for the other types of Miras according to their relative frequency of occurrence. We adopted the mass loss rate given by Gerhz and Woolf (*Ap. J.* **165**, 285, 1971).

It was found that the flow of gas being returned to the galactic plane is $3 \times 10^{-9}\,\mathfrak{M}$ pc^{-2} yr^{-1}. This value is one order of magnitude larger than the value estimated from stellar deaths and four times larger than the value estimated by Gerhz and Woolf (1971).

The energy input from Miras was found to be

$$\dot{U} = 3 \times 10^{-27} \text{ ergs cm}^{-3}\text{sec}^{-1} \quad .$$

This quantity is uncertain by a factor of four due to uncertainties in the mass loss rate and the number densities. This accounts for 15% of the energy input required in the solar neighborhood, $\dot{U}_0 = 2 \times 10^{-26}$ ergs cm^{-3} sec^{-1}. Because the uncertainties are so large this process may dominate the energy input or be completely negligible. Our estimate is about the same as that from expanding envelopes of supernovae and is half the current estimates of the energy input from low-energy cosmic rays.

Since the Mira stars are concentrated towards the Galactic center, we have extrapolated the density of Miras in order to estimate the value of the energy input at 5 kpc from the Galactic center, obtaining

$$\dot{U} = 2.3 \times 10^{-26} \text{ ergs cm}^{-3} \text{ sec}^{-1} \quad .$$

A SPECTROSCOPIC STUDY OF THE MOLECULAR CONSTITUENTS OF DARK CLOUDS

F. H. CHAFFEE, JR.
Mount Hopkins Observatory
S. E. STROM AND B. LUTZ
State University of New York at Stony Brook
AND
J. G. COHEN
University of California at Berkeley

A preliminary study of three heavily reddened B stars in the ρ Oph cloud has been carried out. Spectrograms with a dispersion of 1.3 Å mm^{-1} were obtained with the Mount Hopkins 60-inch telescope using a Kron electronic camera and a Cassegrain echelle spectrograph. For the two most heavily reddened stars (HD 147701 ($U = 8.84$) and HD 147889 ($U = 8.55$)) lines of interstellar CN and CH^+ have been detected, scaling approximately with optical depth, while CH has not been found. For HD 147889 the interstellar Ca II K line is weaker, by more than a factor of 3, than that in the other stars.

It is suggested that the lack of detectable CH results from the influence of the stellar radiation field on the interstellar cloud. The weak K line does not appear to be caused by unusual ionization conditions in the cloud but by an actual depletion of free Ca. If this depletion were caused by Ca adhering to the grains, the interstellar extinction law might be affected by the augmented grain size distribution.

Comparison of OAO far uv data with near IR photometry suggests that the size distribution has indeed been altered toward larger particles in the ρ Oph cloud complex. Such accretion of metals onto the grains in high den-

sity regions has important implications for the thermal balance in such regions.

HIGH-RESOLUTION STELLAR AND CIRCUMSTELLAR SPECTRA OF SiO AND CO AT 4μ AND 5μ

T. R. GEBALLE AND E. R. WOLLMAN*
Department of Physics, University of California, Berkeley
AND
D. M. RANK
Lick Observatory, Board of Studies in Astronomy and Astrophysics, University of California, Santa Cruz

A tandem scanning Fabry-Perot interferometer has been used with the Lick 120-inch telescope to obtain 0.18 cm^{-1} resolution spectra of six bright infrared stars (α Boo, α Sco, α Ori, α Her, R Leo, W Hya) in a 5-cm^{-1} wide frequency interval near the fundamental rotation-vibration band center of $C^{12}O^{16}$, 2140 cm^{-1} (4.7μ). Almost all observed spectral features can be attributed to lines of $C^{12}O^{16}$, $C^{13}O^{16}$, and $C^{12}O^{18}$. The observed spectra were analyzed by fitting them to an assumed isothermal shell model whose parameters included rotational and vibrational temperatures, column density of $C^{12}O^{16}$, the isotopic abundance ratios C^{12}/C^{13} and O^{16}/O^{18}, and a turbulent linewidth. The synthetic stellar spectrum was then convolved with the Fabry-Perot transmission function. The CO column densities in the stars range from $10^{20.0}$ in α Boo to $10^{20.7}$ in α Ori, in all cases about two orders of magnitude less than the predictions of Goon and Auman (1970). C^{12}/C^{13} varies from 8 in α Ori to 3 in W Hya. An absorption feature at the frequency of a transition of $C^{12}O^{18}$ indicates that O^{16}/O^{18} is 25 in W Hya, 40 in α Boo, and 50 in α Her, while in the other three stars an upper limit of 100 may be set. O^{16}/O^{17} is greater than 100 in all six stars studied.

The infrared object IRC +10216 has also been observed near 4.7μ. Only the R3, R4, R12, and R13 lines of the fundamental vibration band of $C^{13}O^{16}$ have been detected (observation of the 1–0 $C^{12}O^{16}$ lines is blocked by terrestrial absorption). Preliminary analysis indicates a rotational temperature for the CO of about 300° K. The observed CO presumably lies in the 2″ diameter shell detected by Toombs et al. (1972).

This work was partially supported by the National Aeronautics and Space Administration Grants NGL 05-003-272 and NGR 05-003-452.

*National Science Foundation Fellow.

REFERENCES

Goon, G., and Auman, J. R. 1970, *Ap. J.* **161**, 533.
Toombs, R. I., Becklin, E. E., Frogel, J. A., Law, S. K., Porter, F. C., and Westphal, J. A. 1972, *Ap. J. (Letters)* 173, L71.

COPERNICUS — HALF A MILLENIUM IN RETROSPECT

KAREL HUJER
University of Tennessee

The anniversary of the birth of Copernicus five hundred years ago, 19 February 1473, offers an excellent opportunity to review and analyze the growth of scientific ideas in the field of astronomy and physical science in general. The scientific world will commemorate this most significant milestone in the history of science, synonymous with the coming of the Renaissance, which was destined to immensely affect trends in the development and character of Western civilization.

Copernicus is usually considered almost a contemporary of our time, associated with the new astronomy. Historians of science, at present, place him alongside ancient Greek philosophers. If we consider the transformation of astronomy since the beginning of the twentieth century, then the last fifty years represent not only intellectually greater distance that separates us from the year of the publication of *De Revolutionibus* in 1543, but even surpass the time elapsed since Aristotle.

Copernicus, merging with the ancient schools of thought, was entirely dependent on Aristotelian concepts. His work merely corroborated Ptolemy's *Almagest* when he dropped the epicycle of each planet but preserved all others because he adhered to the circular orbits of celestial bodies. His reform of the solar system was therefore in the tradition of Pythagorean

mathematicism, just as Kepler's laws, with matter having no inherent physical property. Dynamization of planetary motion with Newton reached the climax of deterministic mechanization and with William Herschel the closed universe finally sprung open to infinity.

At present in the light of modern, Einsteinian physics, the Copernican system, its Euclidean space in conflict with a closed universe, is just as antiquated as Bohr's or Rutherford's atom, whose model is still drawn in our textbooks. With the constant stream of new discoveries secured by the sophisticated tools of modern astrophysical technology, the semimythological universe of Copernicus remains a superb monument, an enduring memorial, and a stepping stone towards man's ever-widening horizons of his universe and its cosmology.

REDDENING AND INFRARED EXCESSES IN T TAURI STARS

CATHERINE L. IMHOFF
The Ohio State University

Three different derivations of the infrared excesses in T Tauri stars are discussed, including one by the author. It is shown that the various original assumptions on the intrinsic colors of the stars and the pertinent extinction law in each derivation have a dominant influence on the derived excesses. One may conclude that the uncertainties in the derived excesses are too large to aid in discovering the origin of those excesses.

JOVIAN ROTATIONAL PROFILES FOR 1970 AND 1971

JAY L. INGE
Planetary Research Center, Lowell Observatory

Over 800 measurements of the positions of 62 features in Jupiter's atmosphere have been made using blue-light photographs of the planet. The photographs were obtained in 1970 and 1971 by the International Planetary Patrol. Measurements for each year span a 25-day period, centered about opposition. Orthographic grids, superimposed on projected images of Jupiter, provided a consistently accurate method for determining positions of features. From the drift in longitude of the features with respect to Systems I and II, rotational periods were derived using tables given by Peek (1958). By combining the data from various latitudes, we have constructed detailed, short-term rotation profiles.

These short-term rotation profiles agree in general with published multiple-year profiles (Chapman 1969; Pokorny 1970), although differences in detail are evident. Rotation periods were found to be progressively shorter from the equator outward to the northern and southern edges within System I. Periods up to 30 seconds shorter than the mean of $9^h50^m30^s$ were measured near the edges. Features near the equator maintained periods similar to the System I mean. In 1971 features were found to have unusually slow rotation rates at latitudes between $+15°$ and $+30°$, and between $-10°$ and $-20°$. The rotation period of one feature was found to be nearly two minutes slower than the mean for System II of $9^h55^m40^s.6$.

This research is supported by NASA research grant NGR-03-003-007.

REFERENCES

Chapman, C. R. 1969, *J. Atmos. Sci.* **26**, 986.
Peek, B. M. 1958, *The Planet Jupiter* (London: Faber and Faber).
Pokorny, Z. 1970, *Bull. Astr. Inst. Czech.* **21**, 318.

A T ASSOCIATION IN CHAMAELEON

EUGENIO E. MENDOZA V.
Instituto de Astronomía, Universidad Nacional Autónoma de México, Mexico City, D. F., Mexico

Results are reported of an Hα survey made in a dark region in Chamaeleon (11^h and $-77°$). In an area $1°.3 \times 1°.6$, 24 objects show Hα in emission from the 12th to the 17th photographic

magnitude, approximately. Slit spectra and Schmidt (ultraviolet and red) spectra, indicate that these objects belong probably to a nearby T association.

MONTE-CARLO TREATMENT OF LYMAN-α RADIATION IN AN INHOMOGENEOUS SPHERICAL ATMOSPHERE

SARMA B. MODALI
Wolf Research and Development Corporation
Riverdale, Maryland

A Monte Carlo technique involving Stokes vectors developed earlier (Modali, Brandt, and Kastner 1972) is extended to obtain the state of polarization and intensity of solar Lyman-α photons as they diffuse through an inhomogeneous spherical geocorona. As a check the program was run for the case of a very thin shell with large radius of curvature as an approximation to a plane-parallel atmosphere; the results obtained for Rayleigh scattering and Lyman-α resonance scattering for different optical depths are in excellent agreement with the earlier results.

A model hydrogen atmosphere was taken from Meier and Mange (1970), in which the hydrogen density varies from 3×10^7 cm^{-3} at 100 km to 10 cm^{-3} at 100,000 km altitude, and the temperature is constant at 1100° K. The fine structure of Lyman-α and the Doppler redistribution of frequencies are taken into account. The incoming beam of photons is assumed to have a rectangular frequency profile as a simulation of the incident solar flux. The calculated diffuse intensities are compared with the observations of OGO IV as reported by Meier and Mange (1970), and agreement is excellent. In addition, the degree of polarization as a function of solar zenith angle is shown.

REFERENCES

Meier, R. R., and Mange, P. 1970, *Planet. Space Sci.* **18**, 803.
Modali, S. B., Brandt, J. C., and Kastner, S. O. 1972, *Ap. J.* **175**, 265.

TEMPERATURES OF URANUS AND NEPTURE AT 24 MICRONS

DAVID MORRISON AND DALE P. CRUIKSHANK
Institute for Astronomy, University of Hawaii, Honolulu

The temperatures of Uranus and Neptune, as measured in the 17- to 28-μ spectral band, are $54.7 \pm 1.^{\circ}8$ K and $57.2 \pm 1.^{\circ}6$ K, respectively, The temperature difference is significant at the 1.5 σ level. In both planets the observed radiation probably arises high in the atmosphere in the strong pressure-induced H_2 band.

AN EXPERIMENT TO DETECT RELATED OPTICAL AND RADIO PULSES OF ASTROPHYSICAL ORIGIN

EON O'MONGAIN*
Mount Hopkins Observatory

A 10-meter diameter optical reflector and two 15-foot radio reflectors are being used to search for electromagnetic pulses which might be associated with gravitational pulses or supernova explosions. For the data analysis, use is being made of disperion in the interstellar medium to eliminate pulses of terrestrial origin. This dispersion causes radio pulses to arrive with a time delay proportional to the integrated electron density to the emitting object, and inversely proportional to the square of the frequency used. Detection of pulses could contribute to an understanding of gravitational collapse processes while the absence of pulses can place interesting constraints on the coupling between gravitational and electromagnetic emission mechanisms.

Searches for pulses related to gravitational radiation are being concentrated on the Galactic center, while searches for similar or supernova type events are being made on Andromeda and the Coma cluster of galaxies.

Preliminary calibration and observations indicate a sensitivity of 10^{-26} ergs cm^{-2} s^{-1} Hz^{-1} at ground level for the optical channel, and 10^{-20}

*National Academy of Sciences, Post-doctoral Resident Research Associate.

ergs cm^{-2} s^{-1} Hz^{-1} for the radio can be achieved with little problem from terrestrial emissions.

This work was supported by a Smithsonian Research Award.

THE ATMOSPHERES OF THE VISUAL BINARY HR 1886 AND HR 1887

GERALDINE J. PETERS
University of California, Los Angeles

The spectra of each component of the wide visual binary HR 1886 and HR 1887 are interpreted with the aid of the Princeton *UV*-line-blanketed model atmospheres. The spectral types of these sharp-lined stars are B1 and B0, respectively. An effective temperature of 24,500° K and $\log(g) = 4.0$ were obtained for HR 1886 from ionization balance of Si III–Si IV and S II–S III. Similarly, from ionization balance of N II–N III, O II–O III, and Si III–Si IV an effective temperature of 28,600° K and $\log(g) = 4.0$ were determined for HR 1887.

It was necessary to include a microturbulent parameter, ξ_T, of 4 km sec^{-1} for HR 1886 and 7 km sec^{-1} for HR 1887 in order to eliminate a systematic increase of oxygen abundance from O II lines with increasing equivalent width.

The observed Hγ profiles of HR 1886 and HR 1887 closely fit theoretical profiles computed from the "unified" theory of Stark broadening (Videl, Cooper, and Smith 1972) with $\log(g) = 4.0$ and $T_{\text{eff}} = 25{,}200°$ K and $T_{\text{eff}} = 28{,}640°$ K, respectively.

With the exception of S III, the derived elemental abundances are the same in both stars. The abundances of C, N, O, and Si are about 0.2 dex lower than the currently accepted solar values; all other elements have solar abundances. The effective temperature determined for HR 1887 agrees exactly with the temperature predicted by the angular-diameter temperature scale. However, the temperature of HR 1886 is higher than the angular diameter measurements predict for a B1 star.

CARBON STARS WITH PECULIAR RED SPECTRA

PAUL M. RYBSKI
Lindheimer Astronomical Research Center
Northwestern University

A program of low-dispersion observations of carbon stars in the spectral range 4700 Å–6700 Å has resulted in the discovery of CaCl absorptions of varying strength in three long-period variable stars. Multiple observations have allowed the application of constraints to the fraction of the phase of variation during which these features are strongest. The observations also point to the danger of determining a strength for the CaCl absorptions in a given star from only one night's observations of the star.

Observations from this same program suggest that the distinction between the CS and the SC stars (Keenan 1971; Catchpole and Feast 1971) should be made solely on the basis of the presence or absence of C_2 molecular absorption features. Evidence is given that the presence of features attributable to zirconium oxide may be a necessary but not a sufficient condition for including a star in the SC category.

REFERENCES

Catchpole, R. M., and Feast, M. W. 1971, *M.N.R.A.S.* **154**, 197.
Keenan, P. C. 1971, *M.N.R.A.S.* **153**, Short Communication.

TWENTY-MICRON FLUXES OF BRIGHT STELLAR STANDARDS

THEODORE SIMON, DAVID MORRISON, AND DALE P. CRUIKSHANK
Institute for Astronomy, University of Hawaii, Honolulu

Observations made at Mauna Kea Observatory between July 1971 and May 1972 establish relative fluxes in the 17–25 μ band. Based on an absolute flux for α Boo at 20 μ of 1.54×10^{-16} W cm^{-2} μ^{-1} ($m_{20} = -3.32$) derived from shorter-wavelength observations and from interferometric diameter measurements and model atmospheres,